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14. ABSTRACT

In this program the grantee investigated terahertz radiation sources and modulators formed by active metamaterials made with the grantee?s original interdigitated grating gate (DGG) structures on HEMT device layers. The principle of operation is the 2DPs which are confined into artificial dimensions of metamaterial structure in a HEMT and are electrically or optoelectronically excited to seed the electromagnetic radiation.

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Final Report

Project: AOARD-09-4031 "**Study on Active Terahertz Metamaterials**"

May 31, 2010

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Background: "Metamaterial" is defined as an artificially structured electromagnetic material exhibiting extraordinary response to the electromagnetic radiation that is hardly performed in natural fashions. Study on "metamaterial" is now one of the emerging science and engineering fields [1-3]. "Terahertz" staying in between radio and optical frequencies is still an unexplored, but now becoming one of the hottest frequency bands [4] to creating new "active" metamaterial systems [5]. In [5], Chen et al., first demonstrated an "active" transmittance control by 50% of terahertz radiation by implementing an arrayed semiconductor metamaterial structure including Schottky diodes. This is an excellent first-step ignition, but fundamental improvements/breakthroughs are necessary to explore deeper science and technology hidden behind the presence. On such a background, two dimensional plasmons (2DPs) in submicron transistors have attracted much attention due to their nature of promoting emission/detection/manipulation of electromagnetic radiation in the terahertz range [6-10].

Results obtained: In this program the grantee investigated terahertz radiation sources and modulators formed by active metamaterials made with the grantee's original interdigitated grating gate (DGG) structures on HEMT device layers. The principle of operation is the 2DPs which are confined into artificial dimensions of metamaterial structure in a HEMT and are electrically or optoelectronically excited to seed the electromagnetic radiation. The basic structure of the grantee's original is focused on (see Fig. 1) and to be improved so as to enhance the radiation power and to realize coherent, monochromatic radiation. To realize coherent monochromatic terahertz radiation and wavelength selectivity, currently installed vertical cavity structure was improved (see Fig. 2); the cavity Q factor should be drastically enhanced. The device process has been carried out at our own, the Laboratory for Nanoelectronics and Spintronics in RIEC. Together with the high Q cavity installation, injection-locking by photomixed dual-laser irradiation was pursued to realize THz emission of coherent monochromatic radiation. Up to now high reflectivity >90% up to 4.5 THz was confirmed from the fabricated samples (see Fig. 3). Verification and characterization of real operation is now undertaken. In terms of the intensity modulators, the controllability of the transmittance of the 2D plasmonic plane in the DGG-HEMT was numerically analyzed. The finite difference time domain analysis demonstrates that the coupling of THz electromagnetic waves and 2DPs changes with the electron drift velocity and with the sheet electron density in 2DPs (see Fig. 4). The analysis also reveals that the intensity of transmitted waves can be modulated over a wide THz range with an extinction ratio beyond 60% by optimizing the sheet electron density and the drift velocity under nominal area-factor condition (ratio of the 2DP area over the total active channel area) up to 0.6 [11].

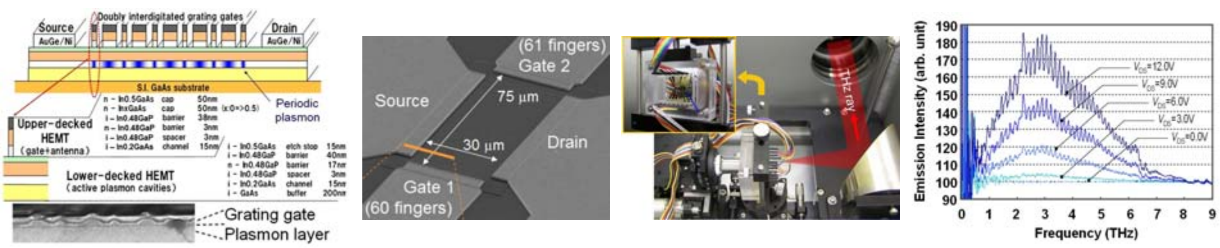

Fig. 1. GaAs-based plasmonic Emitter: structure, SEM image, FTIR setup, and measured spectra.

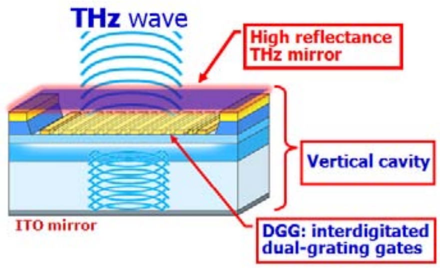

Fig. 2. Schematic view of the high-Q vertical cavity installed in a DGG-HEMT.

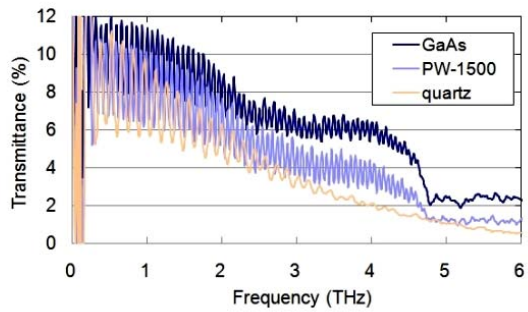

Fig. 3 Transmittance of the fabricated device measured by FTIR. PW-1500 is the case of the real device where ITO is coated on PW-1500 dielectric material coated on a GaAs substrate, showing high reflectivity (low transmittance).

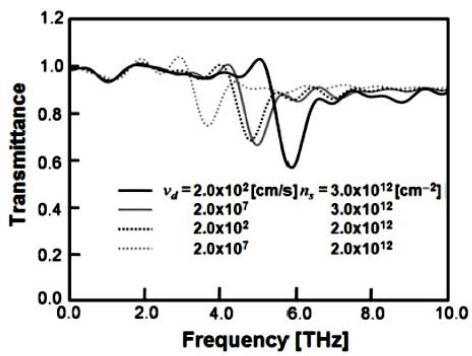

Fig. 5. Transmittance spectra of a DGG-HEMT for various electron drift velocities: v_d and sheet electron density: n_s.

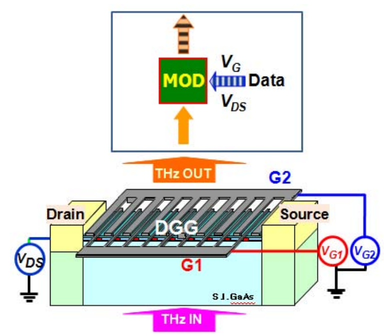

Fig. 6. DGG-HEMT intensity modulator.

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